
NEW YORK CEMENT PRODUCERS ADJUST TO GEOLOGIC COMPLEXITIES

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ABSTRACT

Cement plants in the central Hudson River valley utilize limestones of the Helderbergian Series of the Lower Devonian. Chiefly calcilutites, calcarenites, and cherty calcisiltites, these rocks represent progressively deeper environments, from lagoonal to neritic, with scattered reef deposits. Stratigraphic continuity is marked, and a layer-by-layer analysis shows strikingly constant chemical compositions. The structural picture varies from flat-lying and relatively unfaulted beds on the northwest, through gently folded and faulted beds on the north, to complex overturned beds with closely spaced imbricate faults on the south. Operating techniques are simpler in the north, where grade control is effected chiefly by the initial layout of the faces. In the south, grade control requires flexibility and frequent adjustment of faces or scheduling. A system of quarrying along strike has been developed, grade being computed from a cumulative foot-per cent graph of the critical oxides in each mappable layer. Balancing shovel production among the many faces is simplified by comparing production requirement ratios with ratios of the various types of rock in each face. Drilling and blasting limits are geologically controlled if warranted, or large blasts embracing several rock types are shot and the resulting pile of broken rock is staked along shovel limits.

INTRODUCTION

Every business based on mineral raw materials is a special combination of geology, operating techniques, economics, and people, and each operation should be considered unique. The cement plants of the central Hudson Valley have enough characteristics in common and enough specific differences to warrant discussion as a group. Their stratigraphy is the same, but their geologic structures are different, and it is possible to present these in an orderly progression of complexity, and to describe the ways in which a geologist can help with the specific problems in each situation.

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GEOGRAPHY AND STRATIGRAPHY

There are thirteen cement plants in New York State, spread from Buffalo on the west to Rosendale on the south. The two Buffalo plants use limestone brought in by boat from Michigan, and the Rosendale plant is primarily a natural-cement producer. One other plant at Glens Falls, the northernmost, quarries an Ordovician limestone. All others operate in the Lower Devonian limestones of the Helderbergian Series. One plant lies just southeast of Syracuse; the rest are adjacent to or within the central Hudson River valley and are shown in figure one.

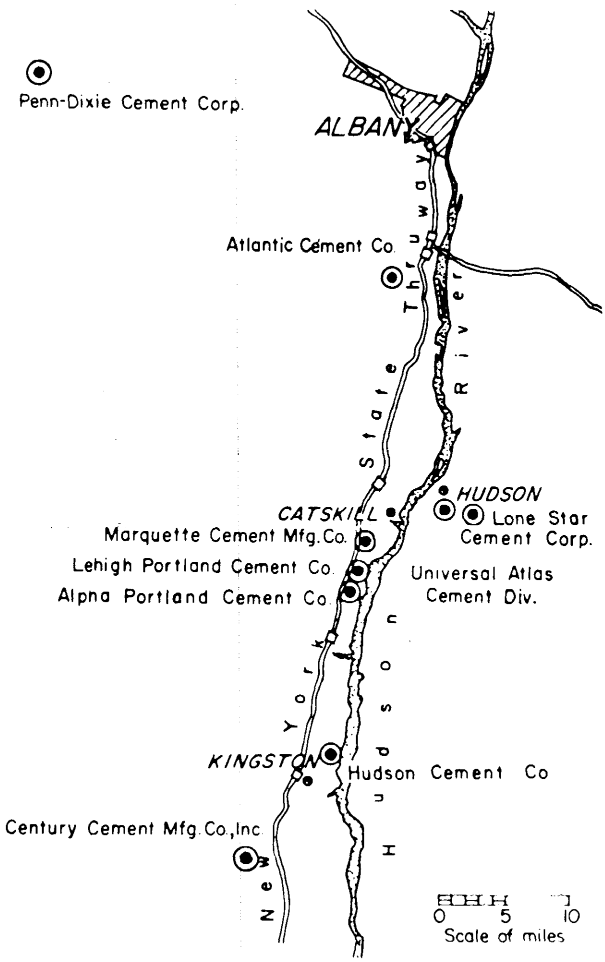

FIGURE 1. Cement Properties in the Central Hudson Valley of New York.

The Lower Devonian beds quarried for cement rock are flat-lying on the west, passing eastward into a region of gentle dips and widely spaced eastward-dipping thrust faults. Southward from the confluence of the Mohawk and Hudson Rivers near Albany, the geology gets more complex, as the Hudson Highlands are approached, and the map pattern reflects overturned folds of varying plunges, cut by closely spaced thrust faults, which are themselves folded. The limestones vary from lagoonal calcilutites to calcarenites to neritic cherty calcisiltites. Reefs are scattered and thin.

The base of the carbonate sequence is formed by Ordovician shales and graywackes. Above an angular unconformity lies the Silurian Rondout formation. The dolomite members of this formation have supplied the raw material for the natural-cement producers of great historic importance. Only one small plant, the Century Cement Manufacturing Company, still operates in these beds at Rosendale. As a matter of stratigraphic interest, it is now considered by Rickard (1964) and others that the Silurian-Devonian contact lies within the Rondout

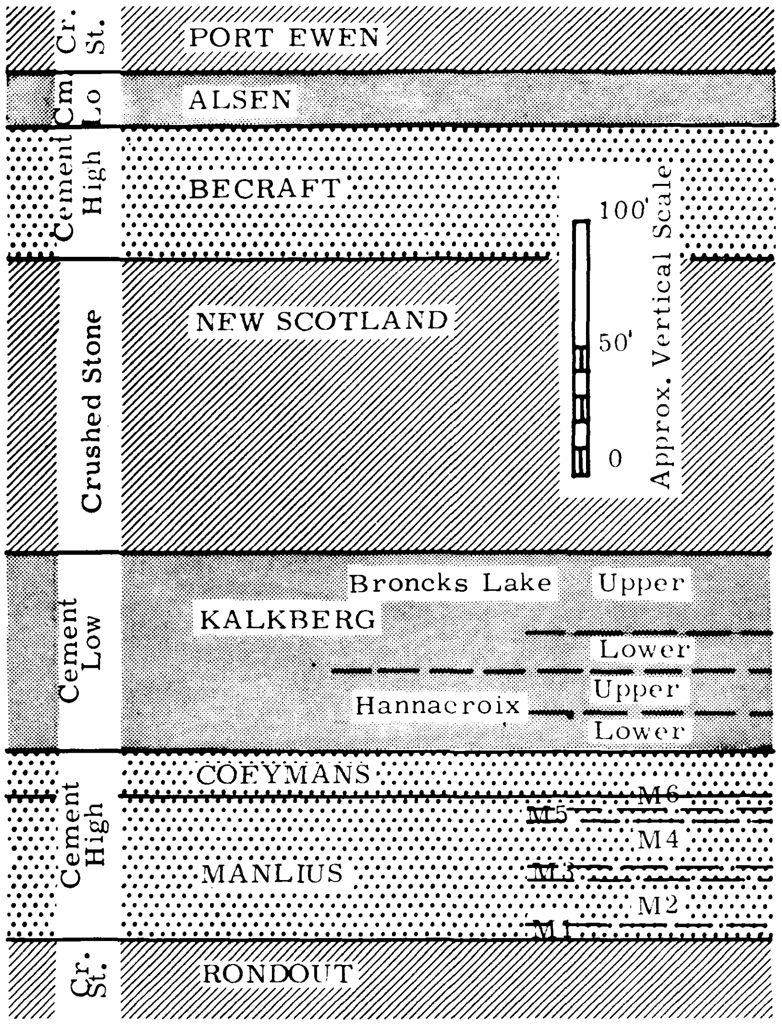

FIGURE 2. Helderbergian stratigraphy. Economic use for each formation is shown at left. ("Cr. St." stands for crushed stone; "Cement High" stands for high-carbonate limestone; "Cement Low" and "Cm. Lo" stands for low-carbonate limestone.)

formation, between the Glasco Limestone and the overlying Whiteport dolomite.

Helderbergian stratigraphy, shown in figure two, embraces, in ascending order, Manlius, Coeymans, Kalkberg, New Scotland, Becraft, and Alsen Formations. A column has been added to indicate the economic use for each stone; either crushed stone, low-carbonate limestone (one furnishing most of the SiO_2

requirements for portland cement and a portion of the CaO needs), or high-carbonate limestone (one furnishing the bulk of the CaO requirements). For surface mapping and quarry control, the rock units along the entire central valley west of the river have been subdivided by Dunn and Rickard (1961) into members of surprising north-south continuity parallel to the Devonian shore. All of these beds have physical characteristics and thicknesses that enable recognition throughout any one property. (To the east of the river the detailed subdivisions are not so clear.) The practical benefits of understanding these stratigraphic details include: unraveling of the structure, quick calculation of grade, a check on chemical analyses, and reduced diamond-drilling costs.

STRUCTURAL GEOLOGY

The structurally simplest rocks, those at the Howe's Cave plant west of Albany, are flat-lying beds, of undisturbed "layer cake" geology; these need not be discussed further. Rock units in the next plant going to the south display broad open folds, with widely spaced low-angle faults dipping to the east.

In the central portion of the belt, there are three plants to the west that have operating faces with both simple and complex geology. In the broad central syncline, it has been possible in the past to operate along a single unfaulted limb. However, at the margins of the syncline, the picture is similar to that of the southernmost plants, one of which has been described in detail by Dunn (1961).

QUARRY CONTROL TECHNIQUES

The greatest value of applied geology is realized when it is used in day-to-day quarrying, in order to provide a continuing quality-control program.

The simplest method of control, applicable in the quarries with flat-lying beds, is by initial quarry lay-out. Analysis of drill-hole samples gives the oxide content of the drill hole, and that's it. If chemical additions are required—and they always are—they are accomplished by later adjustments; the alumina content can be increased by adding shale, clay, or diaspore shale; adding sand, shale, or clay increases the silica content; iron can be increased by adding one of many possible "sweeteners." From this situation of virtually no operating changes, quarrying operations progress in complexity to what amounts to the shot-by-shot analysis necessary in the southern plants.

Drilling

Coring by diamond drilling is used to some degree in almost all plants. However, even where done on a several-hundred-foot grid, it must be supplemented by detailed observation of daily production analyses. At Atlantic Cement, drilling in the immediate quarry area was on 200- and 400-foot patterns, with reconnaissance drilling correlated with outcrop mapping over the whole property. At Hudson Cement, drills were spotted irregularly to help with the detailed mapping and were generally called for to help decipher the structure below a fault.

Once the detailed stratigraphy has been established, a much closer control of exploratory drilling is possible. For instance, if the quarry is to be limited by a magnesian bed at the floor, it is not necessary to drill any more than a few feet of that bed. In such situations the geologist need not stay at the drill waiting for each run of core to be pulled in order to stop the drill at the proper time, for, knowing the stratigraphic column in great detail and the average speed of drilling, the geologist can estimate the time when he will be needed at the drill. The alternative, to play it safe and over-drill, involves additional unnecessary costs. This is but one of many ways by which a geologist can save money for his employer.

In one case, the fact that the geologists had established a pattern of continuity to the chemical analyses of each unit enabled them to recognize a series of erroneous chemical analyses which might have discouraged further testing of the property.

When the chemical results were checked, it was found that the beds were indeed of the predicted composition and that those first chemical analyses had been wrong. At the same property, it was possible to recognize magnesian metasomatism along faults. Had the core been analyzed by the common 10-foot interval method, this would have been misinterpreted, possibly leading to the fatal conclusion that the MgO was irregular and unpredictable.

Detailed Stratigraphy

Careful, layer-by-layer stratigraphy has further benefits. Knowing the units, it is, in a sense, possible to "see through" a "muck pile" after a blast and know whether the quarry floor is being carried too high or too low. The geologist simply climbs over the muck pile, identifies a unit above the broken rock, and hand levels down to the floor.

Further, heavy deposits of clay often occur in the quarry face in faults or in solution cavities opened up along the fault. The geologist, knowing the analyses of the rock units, can forecast the effect of the clay on the broken stone.

Floor Control

Where the structure is fairly gentle, the production rate high, and equipment large, precise floor-grade control is necessary. At one property, using data from the preliminary drilling, a structure-contour map was prepared of the top of the high-magnesian (and therefore unminable) Rondout Formation at the base of the cement series. This map has proved of great service in planning floor location and grade, depth of production drilling, and general grade of the high-analysis limestone.

Strike Quarrying

Where dips are substantial and grade changes sharply from layer to layer, it is necessary to plan faces so as to enable quarrying to follow the strike. Only then will a production face provide a relatively constant product over any distance.

Note in figure three that the quarry faces are being advanced either to the

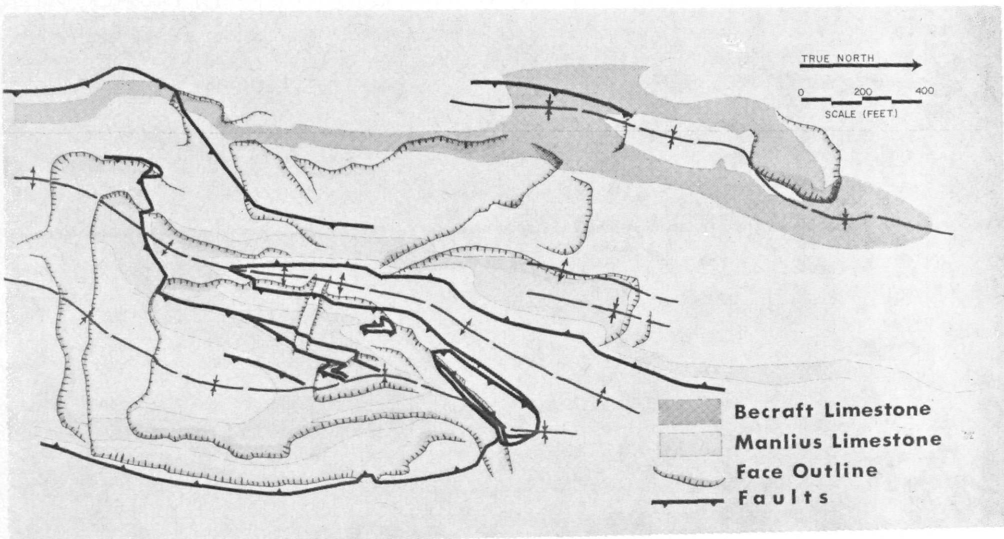

FIGURE 3. Simplified quarry layout with selected geology.

south or to the north. If the faces were carried, say, to the east, across the strike, the quarried rock would be low in MgO in one shot and high in the next. This point, so obvious to a geologist, is not obvious to a quarry operator, and the strike-quarrying technique, once set up, has to be policed, or the operator will succumb to the temptation to get a high production face by shooting at right angles to the strike, thus fouling the analysis of the piles and the sequence of the faces.

Production Ratio versus Face Ratio

At the Hudson Cement Company, at the south end of the cement-quarry belt, crushed stone is produced in addition to cement rock, and from the same faces. The ratio of crushed stone to cement rock produced is called the *production ratio*, an important figure in overall planning, especially in conjunction with the *face ratio*. At any given time, a certain number of quarry faces will be available for production. Each face will have a certain amount of rock for crushed stone and a certain amount of cement rock. The relation between these values is expressed as the *face ratio*. A typical quarry face may have four times as wide an exposure of crushed-stone raw material as of cement rock. Here we say the face ratio is 4 to 1, and it is out of harmony with the production ratio. Hence, additional faces of cement rock are necessary to maintain production at the given production ratio. The object is to provide balanced production with a minimum of shovel moves.

Grade Determination

Mention has been made of the close layer-by-layer mapping, the nearly constant stratigraphic thicknesses, and the uniform composition of each layer over the area embraced by a producing property. This last fact has made it possible to keep preliminary diamond drilling to a minimum, and to do away with the need to catch cuttings from blast-hole drilling in order to determine the grade of a shot. Instead, a cumulative foot-per cent graph has been prepared, based on the averages of several drill holes, for each important oxide. Stratigraphic thicknesses are plotted along the horizontal axis, and the sum of the products of footage times per cent oxide are plotted along the vertical axis. To determine the grade along a vertical line at any point in a face, it is necessary to identify the stratigraphic unit at the top and bottom of the face, find their positions on the graph and subtract the lower foot-per cent figure from the upper and divide by the face height, and in a few minutes you have a usable figure for the composition of the face at that line. Several lines spaced across the face can be averaged quickly to give the average composition of the shot to come. This method has been detailed by Dunn (1961).

Drill and Shovel Limits

Figure four illustrates an example of a complex quarry face. Stratigraphic units are identified, and also, at the top, actual types of stone shoveled are indicated. The limits are based on carbonate analysis, magnesia tolerances, silica limits, or alumina needs. These quarrying limits are set in different ways. The blast holes are sometimes spotted geologically and limited to one kind of stone. More often, a shot involves more than one kind of rock, and the break in shovel portions is indicated to the foreman and shovel operator. If the change in the pile is obscure, stakes are set so there can be no mistake as to the shovel limits. Commonly, different types of rock break differently, and the quarry crew learns the differences. It is also possible, at times, to shoot the different rocks outward in slightly different directions.

Models and Photos

The three-dimensional aspects of the structure as seen along benches is difficult enough for a geologist to understand, and somewhat more difficult for the quarry-

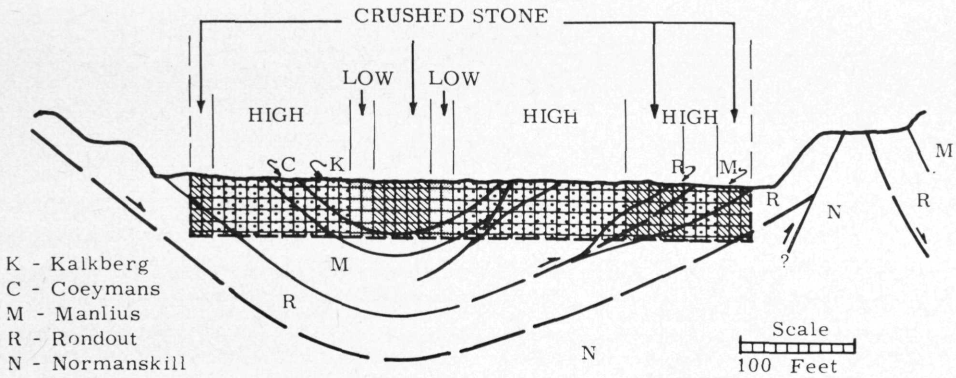

FIGURE 4. Geology and quarrying limits. The terms "high" and "low" refer to the quality of the stone being produced, based on carbonate analysis, magnesia tolerances, silica needs, and alumina needs for cement production.

men. Of great help have been simple Styrofoam models, which can be prepared quickly and inexpensively not only to show the geology, but also to help in decisions as to sequence, thus adding a measure of the fourth dimension. Figure five shows one such model prepared in about 12 hours of a draftsman's time. The clarity of

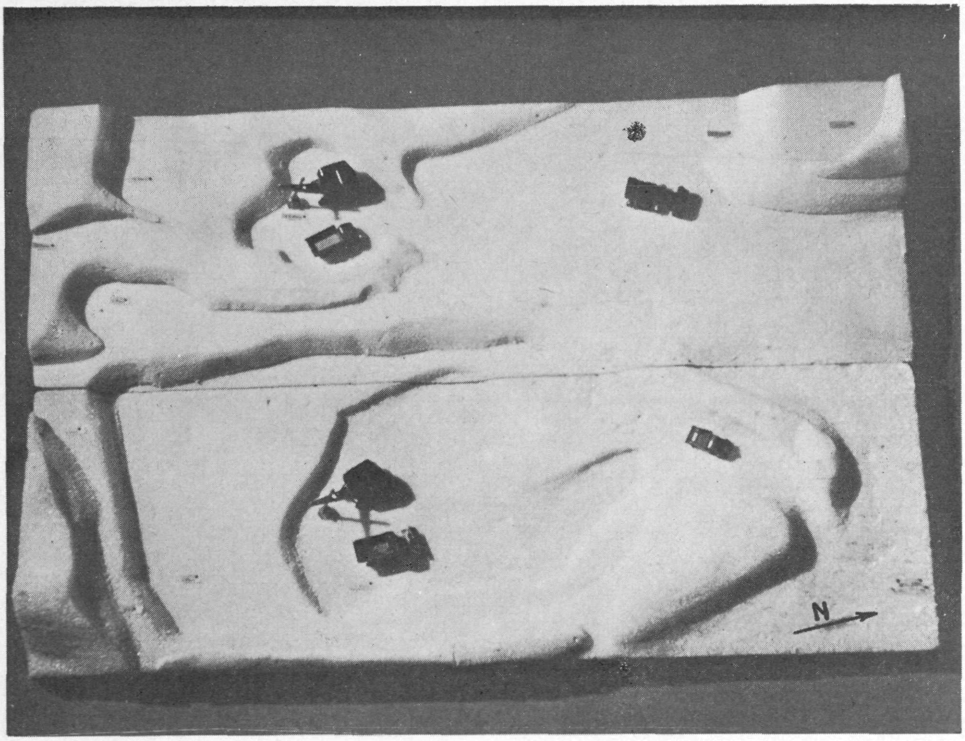

FIGURE 5. Styrofoam model of quarry.

description and economy of time added to a planning conference using such models make them very good investments indeed.

Additional quick visual aids are Polaroid snapshots and simplified sketches of the quarry faces which are given to the various supervisors. (See fig. 6.)

FIGURE 6. View of Hudson Cement Company quarry, Kingston, New York. Field snapshot taken to aid in quality control.

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